Fermilab
Theory Seminar

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B_s mixing and supersymmetry

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Outline

1. Status of B physics
2. $\mathrm{B}-\overline{\mathrm{B}}$ mixing basics
3. Improved prediction of Γ_{12}^{s}
4. Generic new physics
5. Supersymmetry with large $\tan\beta$
6. Conclusions

1. Status of B physics

Want stability of the electroweak scale $v = 174\,\text{GeV}$

$\Rightarrow$ postulate new physics at scale $\Lambda_{\rm NP}$ with $v < \Lambda_{\rm NP} \lesssim 1\,\text{TeV}$.

In low–energy weak processes effects of new physics are suppressed by a factor of $v^2/\Lambda_{\rm NP}^2$ with respect to the Standard Model.

$\Rightarrow$ study processes with suppressed Standard Model contribution

1. Status of B physics

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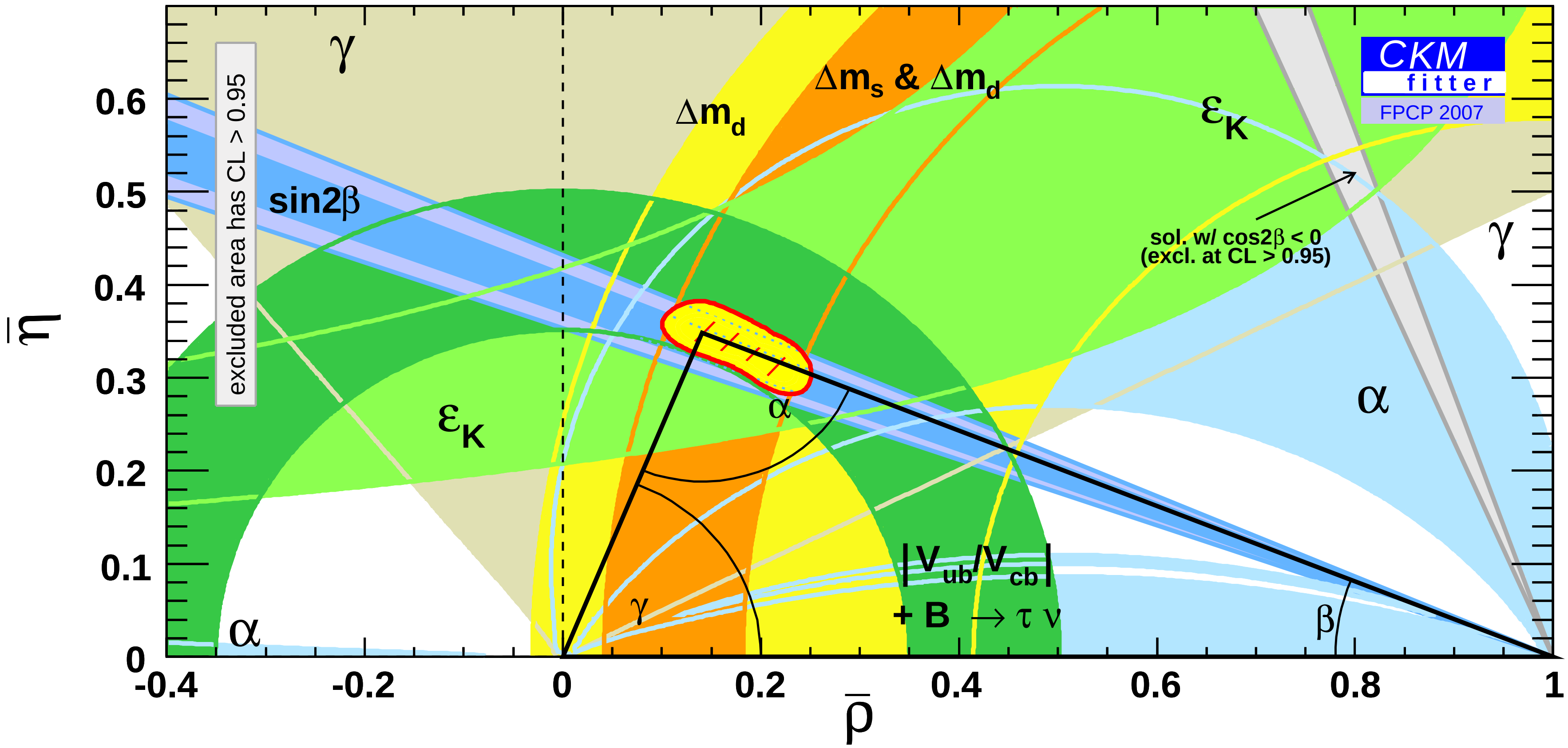
In low–energy weak processes effects of new physics are suppressed by a factor of $v^2/\Lambda_{\mathrm{NP}}^2$ with respect to the Standard Model.

In flavor-changing neutral current (FCNCs) processes of the Standard Model several suppression factors pile up:

- FCNCs proceed through electroweak loops, no FCNC tree graphs,
- small CKM elements, e.g. $|V_{ts}| = 0.04$, $|V_{td}| = 0.01$,
- GIM suppression in loops with charm or down-type quarks, $\propto \frac{m_c^2}{M_W^2}, \frac{m_s^2}{M_W^2}$.
- helicity suppression factor of $\frac{m_b}{M_W}$ or $\frac{m_s}{M_W}$ in radiative and leptonic decays, because FCNCs involve only left-handed fields.

In generic extensions of the Standard Model these suppression factors are absent.

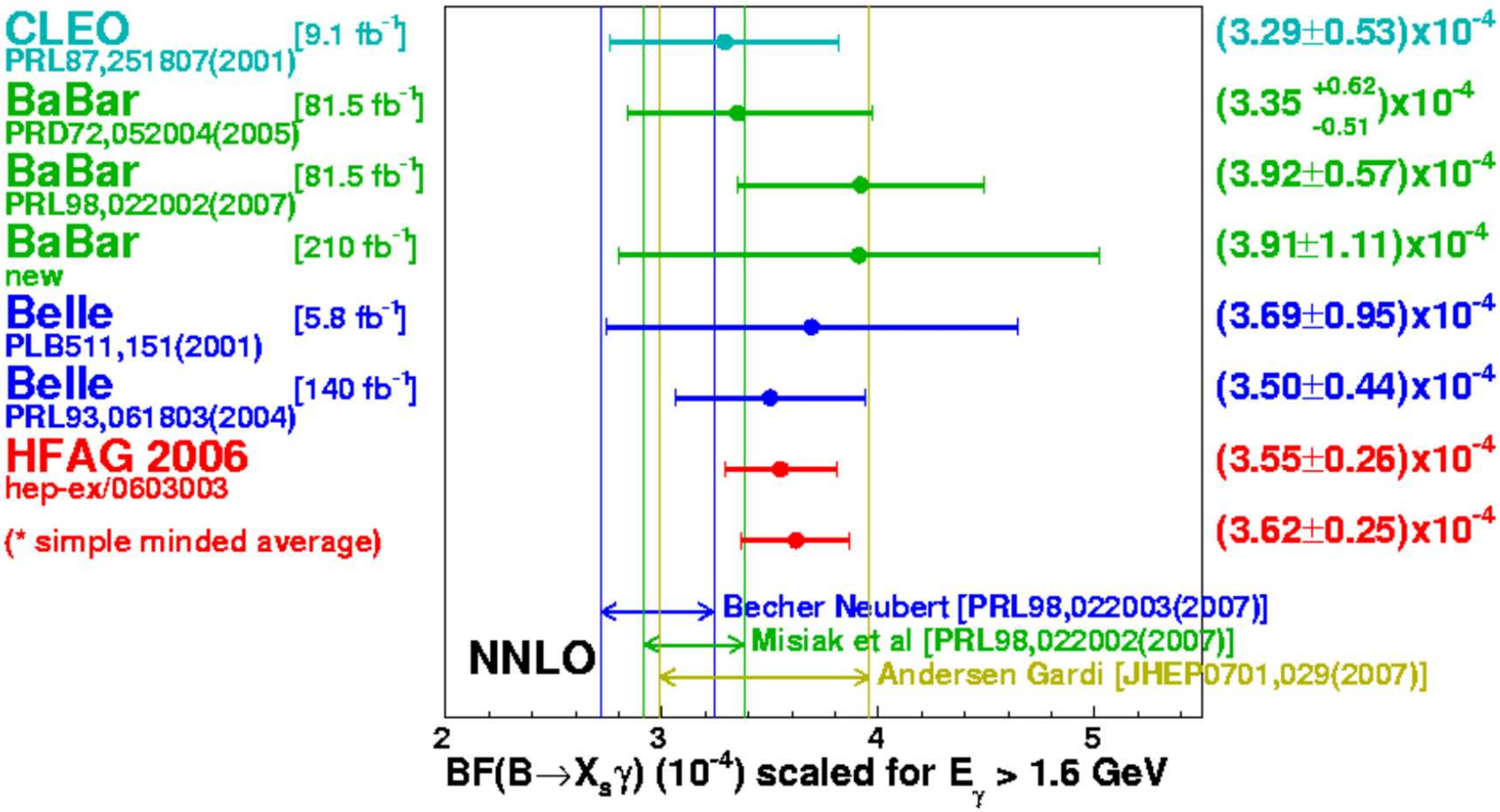
Experimental status of the unitarity triangle



consistent with the Standard Model

CKM mechanism excellently confirmed.

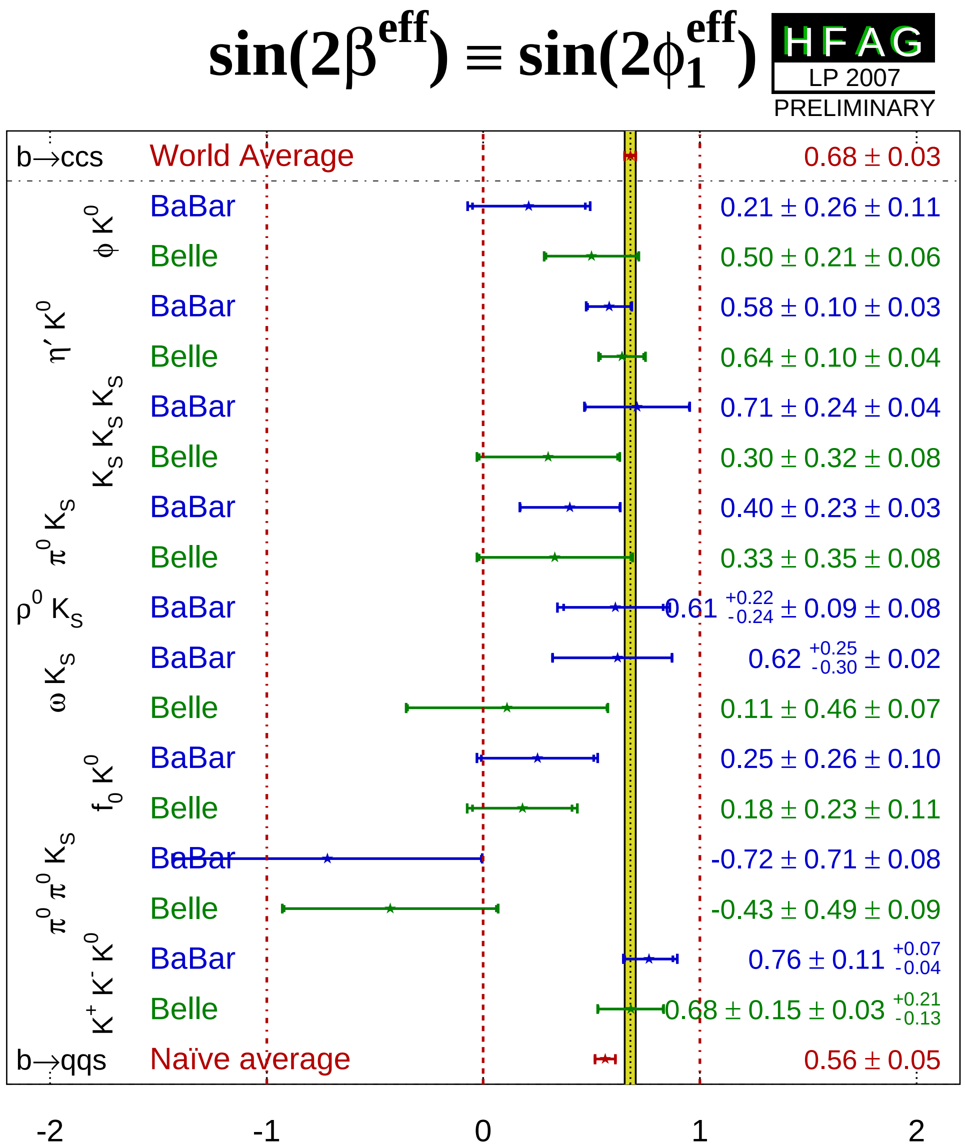
Experimental status of $b \to s\gamma$



consistent with the Standard Model prediction within $\sim 1.5\sigma$:

$$\mathcal{B}(B \to X_s\gamma) \; = \; (2.98 \pm 0.26) \cdot 10^{-4}$$ Becher,Neubert 2006

Experimental status of CP asymmetries in $b \to s$ transitions



Naive average disagrees from the Standard Model expectation by 2.2σ.

Better figure of merit: absolute deviation from the Standard Model.

Physics probed:

Unitarity Triangle:	$b \to d$, $s \to d$, $b \to u$
$B \to X_s \gamma$:	$b_R \to s_L$
$\not{\mathrm{CP}}$ in $b \to s$ transitions:	$b \to s$

$\Rightarrow$ Yukawa sector is the dominant source of flavor violation.

The Standard Model works too well:

Flavor problem of TeV scale physics

	Physics probed:
Unitarity Triangle:	$b \to d$, $s \to d$, $b \to u$
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The Standard Model works too well:

Flavor problem of TeV scale physics

In the Minimal Supersymmetric Standard Model (MSSM) all potential new sources of flavor violation come from the SUSY breaking sector. The success of the flavor physics programs at the B factories and the Tevatron severely constrains the associated parameters in the squark mass matrices.

Minimal Flavor Violation (MFV)

If whatever breaks supersymmetry is flavor–blind, the only source of flavor violation is the Yukawa sector.

$\Rightarrow$ a) The FCNC suppression of the Standard Model essentially stays intact and new physics is suppressed by a factor of $M_W^2/\Lambda_{\rm NP}^2$.
b) Parametric enhancements are still possible, e.g. in scenarios with large $\tan\beta$.
c) MFV still allows for new CP phases, e.g. $\arg A_t$.
d) If MFV is realized above the GUT scale, deviations from CKM–driven FCNCs occur at low energies.

It is difficult to distinguish the Standard Model from MFV new physics scenarios using global fits of the unitarity triangle.
Better: Rare decays, preferably $b \to s$.

Why B_s physics?

- CKM elements in $\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing are well-known.
- Most CP asymmetries are small in the Standard Model.
- The mixing–induced CP asymmetries in $b \to s$ penguin modes can be studied in B_s decays into any final state, while the B_d penguin decays require a neutral K meson. Study $B_s \to \phi\phi$ and $B_s \to K^+K^-$!
- $Br(B_s \to \ell^+\ell^-) \gg Br(B_d \to \ell^+\ell^-)$ in all MFV scenarios.

2. $\mathrm{B}-\overline{\mathrm{B}}$ mixing basics

Schrödinger equation:

$$i\frac{d}{dt}\begin{pmatrix} |\,B(t)\,\rangle \\ |\,\overline{B}(t)\,\rangle \end{pmatrix} = \left(M - i\,\frac{\Gamma}{2}\right)\begin{pmatrix} |\,B(t)\,\rangle \\ |\,\overline{B}(t)\,\rangle \end{pmatrix}$$

3 physical quantities in $\mathrm{B}-\overline{\mathrm{B}}$ mixing:

$$|M_{12}|\,, \quad |\Gamma_{12}|\,, \quad \phi = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

Two mass eigenstates:

Lighter eigenstate: $|\,B_L\,\rangle = p|\,B^0\,\rangle + q|\,\overline{B}^0\,\rangle.$

Heavier eigenstate: $|\,B_H\,\rangle = p|\,B^0\,\rangle - q|\,\overline{B}^0\,\rangle$ with $|p|^2 + |q|^2 = 1.$

with masses $M_{L,H}$ and widths $\Gamma_{L,H}$.
Here B represents either B_d or B_s.

To determine $|M_{12}|$, $|\Gamma_{12}|$ and ϕ measure

$$\Delta m = M_H - M_L \simeq 2|M_{12}|,$$
$$\Delta\Gamma = \Gamma_L - \Gamma_H \simeq -\Delta m \,\mathrm{Re}\, \frac{\Gamma_{12}}{M_{12}} = 2|\Gamma_{12}| \cos\phi$$

and

$$a_{\mathrm{fs}} = \mathrm{Im}\, \frac{\Gamma_{12}}{M_{12}} = \left|\frac{\Gamma_{12}}{M_{12}}\right| \sin\phi.$$

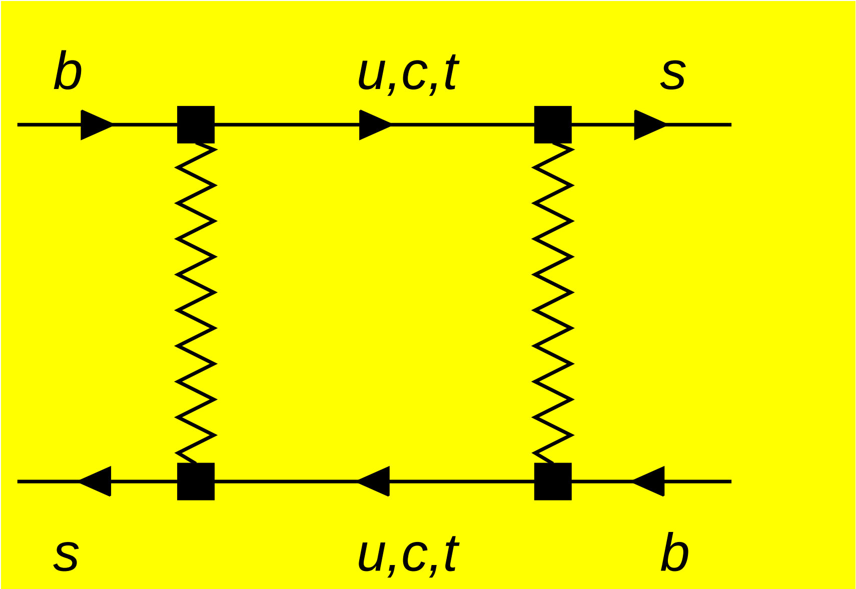
a_{fs} is the CP asymmetry in flavour-specific B decays (semileptonic CP asymmetry). a_{fs} measures CP violation in mixing.

Define the average rate $\Gamma \equiv (\Gamma_L + \Gamma_H)/2$.

Standard Model expectations:

	B_d system	B_s system
$\Delta m \;=$	$0.5\,\text{ps}^{-1}$	$20\,\text{ps}^{-1}$
$\Delta\Gamma \;=$	$3 \cdot 10^{-3}\,\text{ps}^{-1}$	$0.10\,\text{ps}^{-1}$
$\dfrac{\Delta\Gamma}{\Gamma} \;=$	$4 \cdot 10^{-3}$	0.15
$\dfrac{\Delta\Gamma}{\Delta m} = \left\lvert \dfrac{\Gamma_{12}}{M_{12}} \right\rvert \cos\phi \;=$	$5 \cdot 10^{-3} \;=\; \mathcal{O}\left(\dfrac{m_b^2}{M_W^2}\right)$	
$a_{\text{fs}} \;=\; \left\lvert \dfrac{\Gamma_{12}}{M_{12}} \right\rvert \sin\phi \;=$	$-5 \cdot 10^{-4}$	$2 \cdot 10^{-5}$
$\phi \;=$	$-0.9 = -5^\circ = \mathcal{O}\left(\dfrac{m_c^2}{m_b^2}\right)$	$4 \cdot 10^{-3} = 0.2^\circ$ $\;=\; \mathcal{O}\left(\lvert V_{us}\rvert^2 \dfrac{m_c^2}{m_b^2}\right)$

$\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing and new physics



Standard Model:

M_{12}^s from dispersive part of box,
only internal t relevant;

Γ_{12}^s from absorptive part of box,
only internal u, c contribute.

New physics can barely affect Γ_{12}^s, which stems from tree-level decays.

M_{12}^s is very sensitive to virtual effects of new heavy particles.

$\Rightarrow$ $\Delta m \simeq 2|M_{12}^s|$ can change.

and in $\phi_s \simeq \arg(-M_{12}^s/\Gamma_{12}^s)$ the GIM suppression of ϕ_s can be lifted.

$\Rightarrow$ $|\Delta\Gamma_s| = \Delta\Gamma_{s,\mathrm{SM}}\,|\cos\phi_s|$ is depleted

and $|a_{\mathrm{fs}}^s|$ is enhanced, by up to a factor of 200 in the B_s system.

To identify or constrain new physics one wants to measure both the magnitude and phase of M_{12}^s.

$$\rightarrow \qquad \Delta m_s = 2|M_{12}^s|$$

Information on $\arg M_{12}^s$ can be gained from mixing-induced CP asymmetries, in particular $a_{\rm mix}(B_s \to J/\psi\phi)$. This requires tagging, which is difficult at hadron colliders.

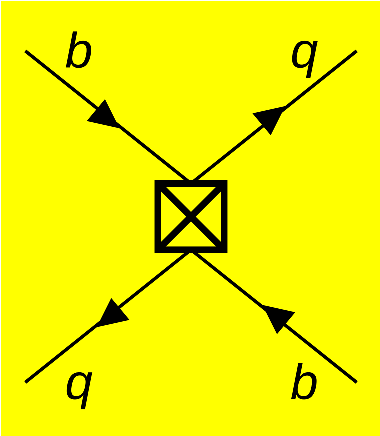
Three untagged measurements are sensitive to $\arg M_{12}^s$:

1. $|\Delta\Gamma_s| = \Delta\Gamma_{s,\rm SM}\,|\cos\phi_s| = \left|\mathrm{Re}\,\dfrac{\Gamma_{12}^s}{M_{12}^s}\right| \Delta m_s$
2. $a_{\rm fs}^s = \left|\dfrac{\Gamma_{12}^s}{M_{12}^s}\right| \sin\phi = \mathrm{Im}\,\dfrac{\Gamma_{12}^s}{M_{12}^s}$
3. the angular distribution of $\overset{(-)}{B}_s \to VV'$, where V, V' are vector bosons.

$$\Rightarrow \text{Want good theoretical control of } \frac{\Gamma_{12}^s}{M_{12}^s}.$$

3. Improved prediction of Γ_{12}^s

Γ_{12} in $\mathrm{B_q}-\overline{\mathrm{B}}_\mathrm{q}$ mixing with $q=d$ or $q=s$ involves two local four-quark operators:



$$Q = \overline{q}_L \gamma_\nu b_L \, \overline{q}_L \gamma^\nu b_L$$

$$Q_S = \overline{q}_L b_R \, \overline{q}_L b_R$$

Theoretical uncertainty dominated by matrix element:

$$\langle \mathrm{B_q} | Q | \overline{\mathrm{B}}_q \rangle = \frac{2}{3} m_B^2 \, f_{B_q}^2 \, B$$

$$\langle \mathrm{B_q} | Q_S | \overline{\mathrm{B}}_q \rangle = -\frac{5}{12} M_{B_q}^2 \, \frac{M_{B_q}^2}{(\bar{m}_b + \bar{m}_q)^2} \, f_{B_q}^2 \, B_S$$

The hadronic parameters $f_{B_q}^2 B$ and $f_{B_q}^2 B_S$ must be computed with lattice QCD. $f_{B_q}^2$ is the decay constant of the B_q meson.

The mass difference Δm_q only involves the operator Q, so that

$$\Delta m_q \propto \langle \, \mathrm{B_q} \, |Q| \, \overline{\mathrm{B}}_q \, \rangle \; = \; \frac{2}{3} m_B^2 \, f_{B_q}^2 \, B$$

Our 1998 prediction including corrections of order α_s and Λ_{QCD}/m_b:

$$\frac{\Delta\Gamma_s}{\Gamma} = \left(\frac{f_{B_s}}{210\,\mathrm{MeV}} \right)^2 [0.006\, B \; + \; 0.172\, B_S \; - \; 0.063]$$

Pathological situation: Both the $1/m_b$ and α_s corrections are large and decrease $\Delta\Gamma_s$, leading to large uncertainties. Moreover B_S dominates over B, so that $\Delta\Gamma_s/\Delta m_s$ depends on B_S/B.

But: These pathologies are an artifact of a poorly chosen operator basis.

A. Lenz, U.N., hep-ph/0612167

One can eliminate Q_S in favour of

$$\widetilde{Q}_S = \overline{s}_L^i b_R^j \, \overline{s}_L^j b_R^i,$$

where i, j are colour indices, which reshuffles terms between the leading order and the sub-leading orders in α_s and Λ_{QCD}/m_b.

The matrix element of $\widetilde{Q}_S$ is almost five times smaller than that of Q_S:

$$\langle B_s|\widetilde{Q}_S|\overline{B}_s\rangle = \frac{1}{12} M_{B_s}^2 \frac{M_{B_s}^2}{(\bar{m}_b + \bar{m}_s)^2} f_{B_s}^2 \widetilde{B}_S$$

Becirevic et al. (2001) find $\widetilde{B}_S = 0.91 \pm 0.09$.

Shigemitsu (HPQCD), Lattice 2006: $f_{B_s}\sqrt{\widetilde{B}_S} = 245 \pm 19$ MeV.

Using the new operator basis:

$$\frac{\Delta\Gamma_s}{\Gamma} = \left(\frac{f_{B_s}}{240\,\text{MeV}}\right)^2 \left[0.160\,B \;+\; 0.058\,\widetilde{B}_S \;-\; 0.041\right]$$
$$= 0.15 \pm 0.05 \qquad \text{for } f_{B_s} = 240 \pm 40\,\text{MeV}.$$

$\Rightarrow$ $\Delta\Gamma_s$ is now dominated by the term proportional to B and the $1/m_b$ corrections are smaller.

f_{B_s} drops out from $\Delta\Gamma_s/\Delta m_s$. Including the uncertainties of the coefficients:

$$\frac{\Delta\Gamma_s}{\Delta m_s} = \left[34 \pm 6 + (17 \pm 1)\frac{\widetilde{B}_S}{B}\right] \cdot 10^{-4}$$
$$= (50 \pm 9) \cdot 10^{-4}$$

Here the matrix elements of the $1/m_b$-suppressed operators are evaluated in the vacuum insertion approximation (i.e. bag factors set to 1).

$$\Delta\Gamma_s \;=\; \frac{\Delta\Gamma_s}{\Delta m_s}\,\Delta m_s^{\text{exp}} \;=\; (0.088 \pm 0.017)\,\text{ps}^{-1}.$$

4. Generic new physics

The phase $\phi_s = \arg(-M_{12}/\Gamma_{12})$ is negligibly small in the Standard Model:

$$\phi_s^{\mathrm{SM}} = 0.2^\circ.$$

Define the complex parameter Δ_s through

$$M_{12}^s \equiv M_{12}^{\mathrm{SM},s} \cdot \Delta_s\,, \qquad \Delta_s \equiv |\Delta_s| e^{i\phi_s^\Delta}.$$

In the Standard Model $\Delta_s = 1$.

The CDF measurement

$$\Delta m_s = (17.77 \pm 0.10 \pm 0.07)\ \mathsf{ps}^{-1}$$

and

$$f_{B_s}\sqrt{B} = 221 \pm 46\ \ \mathsf{MeV}$$

imply

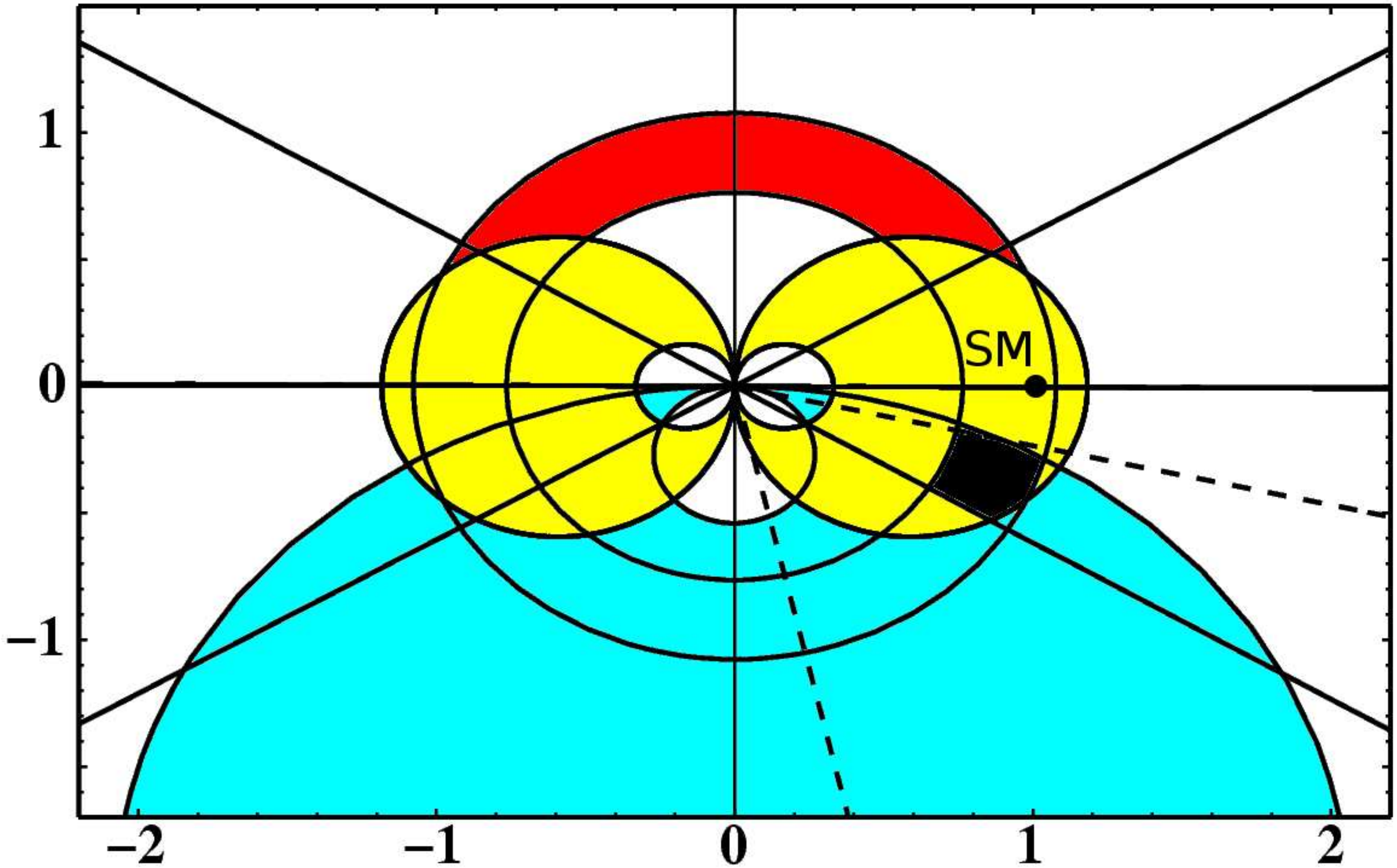
$$|\Delta_s| = 0.92 \pm 0.32_{(\mathsf{th})} \pm 0.01_{(\mathsf{exp})}$$

To further constrain Δ_s we have analysed the CDF data on Δm_s and the DØ data on

- the semileptonic CP asymmetry $a_{\rm fs}^s$,
- the angular distribution in $\overset{(-)}{B}_s \to J/\psi\phi$ and
- $\Delta\Gamma_s$.

Everything presented here only uses 2006 data.

Constraints on the complex Δ_s plane:



We find a deviation from the Standard Model by 2σ.

A closer look at $\phi_s^\Delta = \arg \Delta_s$

The angular distribution in $\overset{(-)}{B_s} \to J/\psi\phi$ is sensitive to $\sin(\phi_s^\Delta - 2\beta_s)$, where $\beta_s = 1.1^\circ$ is the phase of the relevant combination of CKM elements. DØ finds

$$\sin(\phi_s^\Delta - 2\beta_s) = -0.71^{+0.48}_{-0.27}$$

and another solution with opposite sign. DØ measures a combination of the semi-leptonic CP asymmetries in $\mathrm{B_d}$ and $\mathrm{B_s}$ decays:

$$\begin{aligned} a_{\mathrm{sl}} &= (0.58 \pm 0.03)\; a_{\mathrm{sl}}^d + (0.42 \pm 0.05)\; a_{\mathrm{sl}}^s \\ &= \left(-2.8 \pm 1.3_{\text{(stat)}} \pm 0.9_{\text{(syst)}}\right) \cdot 10^{-3} \end{aligned}$$

Using the theory prediction for $a_{\mathrm{sl}}^d = -0.0005 \pm 0.0001$ this implies:

$$a_{\mathrm{sl}}^s = \left(-6.0 \pm 3.2_{\text{(stat)}} \pm 2.2_{\text{(syst)}}\right) \cdot 10^{-3}$$

$$\Rightarrow \qquad \frac{\sin\phi_s^\Delta}{|\Delta_s|} = -1.05 \pm 0.20_{\text{(th)}} \pm 0.78_{\text{(exp)}}$$

Assuming $|\Delta_s| = 1$ the two constraints combine to

$$\sin(\phi_s - 2\beta_s) = -0.77 \pm 0.04_{\text{(th)}} \pm 0.34_{\text{(exp)}},$$

which deviates from the Standard Model value $\sin(-2\beta_s) = -0.04$ by 2σ.

Relaxing $|\Delta_s| = 1$ lowers both the central value and the error, but keeps the deviation at 2σ.

5. Supersymmetry with large $\tan\beta$

in collaboration with Martin Gorbahn, Sebastian Jäger and Stéphanie Trine

Tree-level Higgs sector of the MSSM:

type-II Two-Higgs-doublet model (2HDM):

2 VEV's: v_d, v_d, $\tan\beta \equiv v_u/v_d$.

5 Higgs fields:

$H^\pm$	A^0	H^0	h^0
charged	CP-odd	CP-even	CP-even

Right–handed down-type quarks d_R^I $(I = 1, 2, 3)$ only couple to H_d with $\langle H_d^0 \rangle = v_d$, while the right–handed up-type quarks u_R^I only couple to H_u with $\langle H_u^0 \rangle = v_u$.

The tree-level relations between the Yukawa couplings y_b, y_t and the bottom and top masses are:

$$m_b = y_b v_d = y_b v \cos\beta, \qquad m_t = y_t v_u = y_t v \sin\beta$$

with $v = \sqrt{v_d^2 + v_u^2} = 174$ GeV.

$$\Rightarrow y_b = \mathcal{O}(1) \text{ possible for } \tan\beta \sim 50.$$

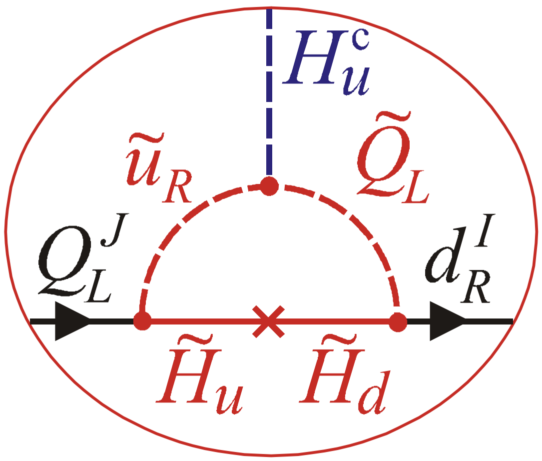
Motivation:

- $\tan\beta \sim 50 \Leftrightarrow y_b$–$y_t$ unification (probes minimal SO(10))
- $g - 2$ invites large $\tan\beta$.

Large $\tan\beta$ scenarios are usually studied in an effective field theory framework, which is exact for $M_{\text{SUSY}} \gg M_{A^0}, M_{H^0}, M_{H^+}, M_{h^0}, v$.

The SUSY–breaking terms lead to loop–induced couplings of H_u to the d_R^I's:
For $v_u \gg v_d$ their contribution to m_b competes with the tree–level term.

Hall, Rattazzi, Sarid



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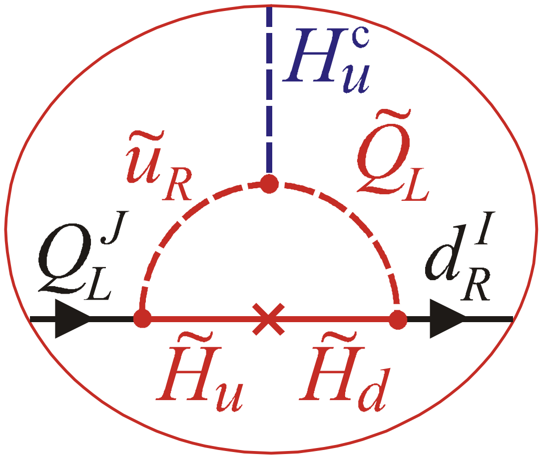


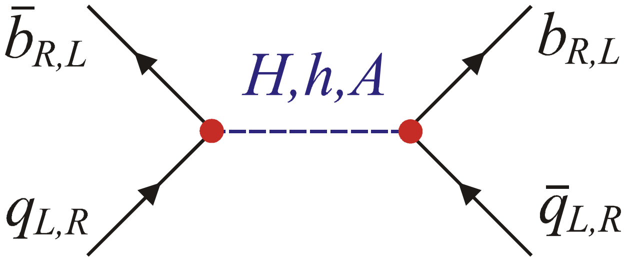
The resulting Higgs sector is a general 2HDM with sizable FCNC couplings of A^0 and H^0, even for MFV. Hamzaoui, Pospelov, Toharia; Babu, Kolda

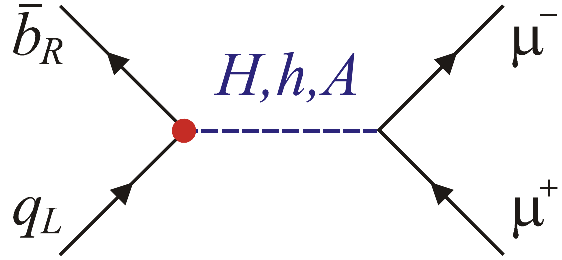
Yukawa interaction of neutral Higgs fields:

$$\mathcal{L}_Y = \kappa^{IJ} \overline{d}_R^I d_L^J \left(\cos\beta h_u^{0*} - \sin\beta h_d^{0*}\right) + \kappa^{JI} \overline{d}_L^I d_R^J \left(\cos\beta h_u^{0} - \sin\beta h_d^{0}\right)$$

FCNC couplings

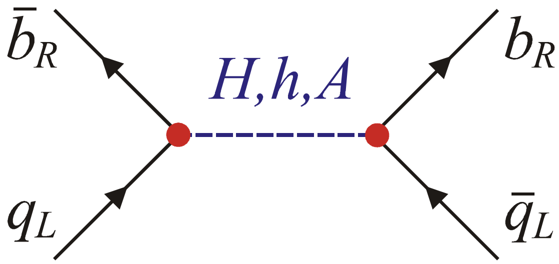
In the effective theory the diagrams for $\mathrm{B_q}-\overline{\mathrm{B}}_\mathrm{q}$ mixing and $B_s \to \mu^+\mu^-$ are tree–level:





$\mathcal{B}(B_s \to \mu^+\mu^-)$ could be enhanced dramatically, the experimental upper bound $\mathcal{B}^{\exp}(B_s \to \mu^+\mu^-) \le 20 \cdot \mathcal{B}^{\rm SM}(B_s \to \mu^+\mu^-)$ already severely constrains the MSSM parameter space.

However: In $\mathrm{B_q}-\overline{\mathrm{B}}_\mathrm{q}$ mixing the leading contribution,



$$\propto \mathcal{F}^- = \frac{\sin^2(\alpha-\beta)}{M_H^2} + \frac{\cos^2(\alpha-\beta)}{M_h^2} - \frac{1}{M_A^2},$$

vanishes, if the tree–level relationship between the masses and the mixing angles α, β is used.

Hamzaoui, Pospelov, Toharia; Babu, Kolda

Trading one $\overline{b}_R q_L$ for $\overline{b}_L q_R$ brings a suppression factor of m_q/m_b, but the Higgs propagators give something non–zero. Only relevant for $q = s$.

Correlation: Δm_s decreases with increasing $\mathcal{B}(B_s \to \mu^+\mu^-)$.

Buras, Chankowski, Rosiek, Sławianowska

Recent updates: Carena, Menon, Noriega-Papaqui, Szynkman, Wagner

Carena, Menon, Wagner

Altmannshofer, Buras, Guadagnoli, Buras,

But: There are other subleading effects, can they compete with the $\frac{m_s}{m_b}$ terms?

Here: Discuss SUSY loop corrections to the Higgs sector.

Previous work: Parry 2006: corrections to $M_{h,H,A}, \alpha, \beta$ with FeynHiggs package, found huge effects

Freitas, Gasser, Haisch 2007: correction $\delta F^- \propto \frac{M_h^2}{M_H^2 - M_h^2}$, large for $M_H \sim M_h$.

Caution: There are many cancellations at work. We take them into account by matching the MSSM Higgs potential to the Higgs potential of a general 2HDM.

Earlier work: Haber, Hempfling 1993; Carena, Espinosa, Quirós, Wagner 1995

The general 2HDM involves 7 quartic self–couplings:

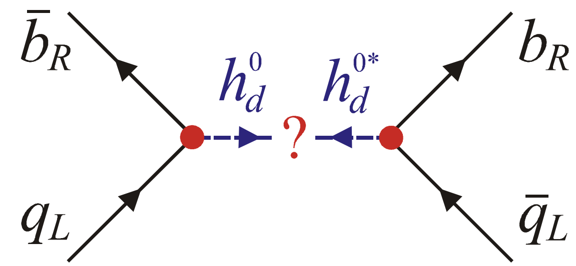
$$\begin{aligned} V \;=\; & m_{11}^2 H_d^\dagger H_d + m_{22}^2 H_u^\dagger H_u + \left[m_{12}^2 H_u \cdot H_d + \text{h.c.}\right] + \\ & \frac{\lambda_1}{2}(H_d^\dagger H_d)^2 + \frac{\lambda_2}{2}(H_u^\dagger H_u)^2 + \lambda_3 H_d^\dagger H_d H_u^\dagger H_u + \lambda_4 H_u^\dagger H_d H_d^\dagger H_u + \\ & \left[\frac{\lambda_5}{2}(H_u \cdot H_d)^2 - \lambda_6 H_d^\dagger H_d\, H_u \cdot H_d - \lambda_7 H_u^\dagger H_u\, H_u \cdot H_d + \text{h.c.}\right] \end{aligned}$$

MSSM at tree–level: $\lambda_1 = \lambda_2 = -\lambda_3$ and $\lambda_5 = \lambda_6 = \lambda_7 = 0$

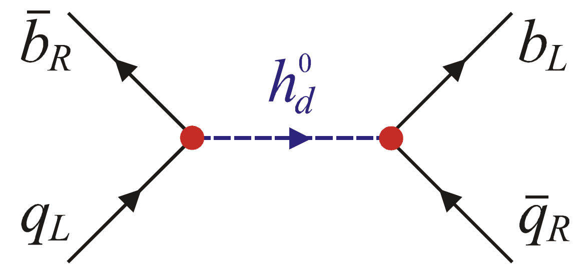
Recalling that $m_{12}^2 = \sin\beta\cos\beta M_A^2 = \mathcal{O}(\frac{1}{\tan\beta})$, one observes that V and $\mathcal{L}_Y$ are invariant under a PQ–type symmetry for $\tan\beta \to \infty$:

$$U(1)_{\rm PQ}: \qquad Q_{\rm PQ}(H_d) \;=\; Q_{\rm PQ}(d_R^I) \;=\; 1, \qquad Q_{\rm PQ}(\text{other}) \;=\; 0.$$

Understand better, why leading effect is zero:

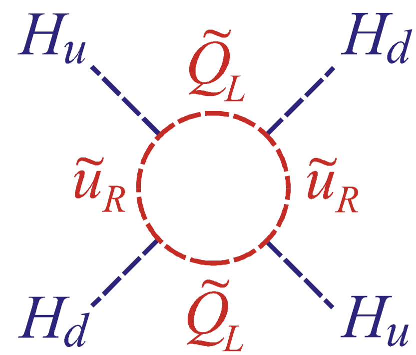


Known subleading $\mathcal{O}(m_q/m_b)$ effect:



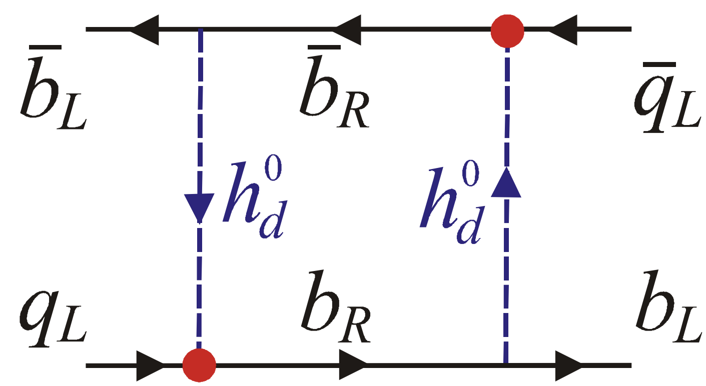
Systematic treatment:

- Calculate all terms in V and $\mathcal{L}_Y$ which involve one power of a small PQ–symmetry breaking parameter. Most relevant term in V is the loop-induced λ_5:



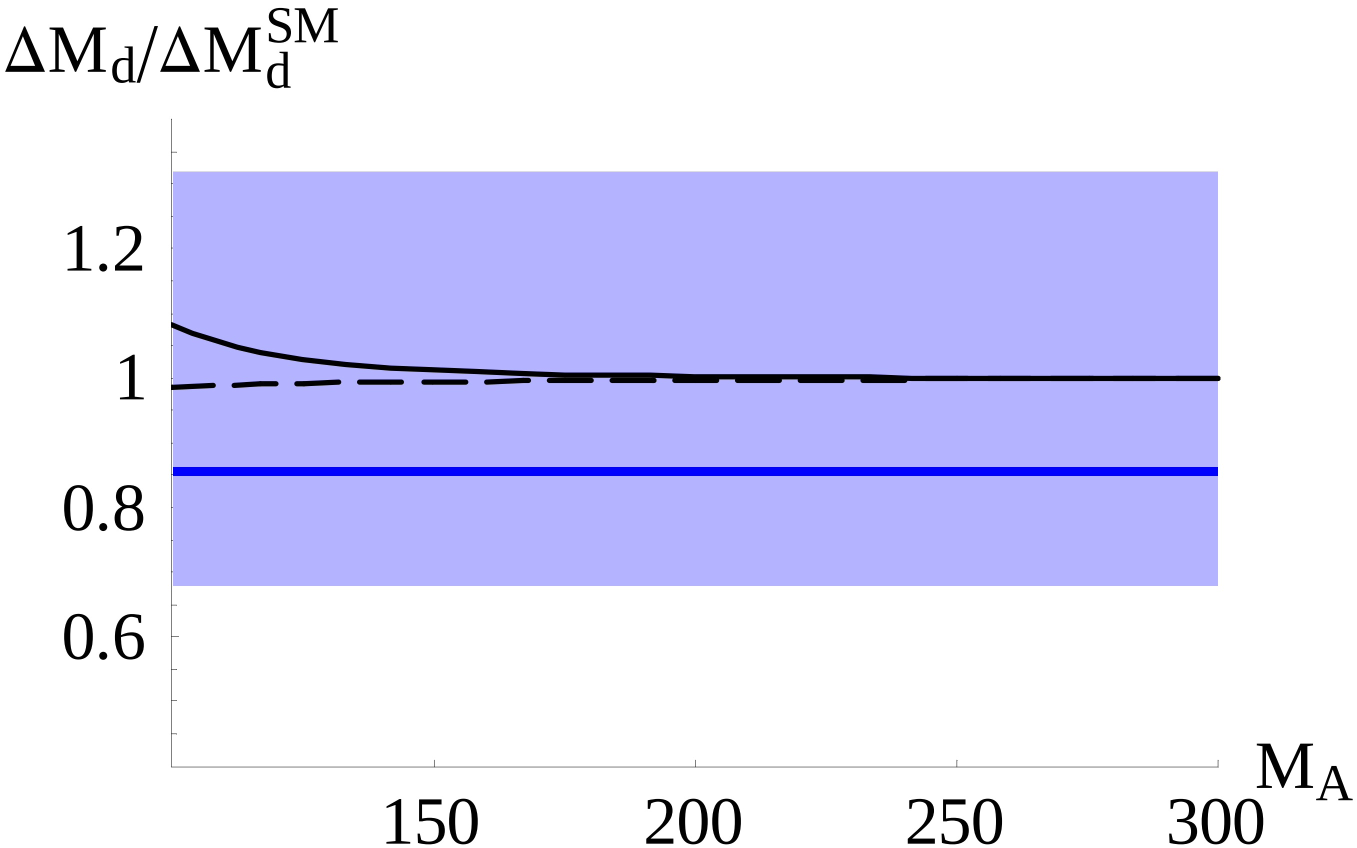
- Include all PQ–symmetry breaking and all parametrically small (e.g. suppressed by m_s/m_b) contributions to $\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing at tree–level (using the effective lagrangian).

- Calculate PQ–symmetry conserving contributions to $\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing at one–loop.



- Study higher–dimensional operators, which give effects of order $\mathcal{O}(v^2/M^2_{\mathrm{SUSY}})$.

Result



for $M_{\tilde{q}} = M_{\tilde{g}} = 0.8$ TeV, $A_{t,b} = 1$ TeV, $\mu = 1.2$ TeV.

Effect hardly exceeds 5%.

$\Rightarrow$ $B_q - \overline{B}_q$ mixing not sensitive to Higgs self–couplings.

6. Conclusions

- B_s physics is a better place to look for new TeV scale physics than global fits to the unitarity triangle.
- A better theory predictions for Γ_{12}^s is available, which improves the analyses of $\Delta\Gamma_s$ and $a_{\rm fs}^s$. In particular

$$\Delta\Gamma_s^{\rm SM} = (0.088 \pm 0.017)\,\text{ps}^{-1}$$

- Tevatron experiments start to constrain the CP-violating phase of M_{12}^s. 2006 DØ data show a 2σ deviation of ϕ_s^Δ from the Standard Model value $\phi_s^\Delta = 0$.
- In the MSSM with large $\tan\beta$ large contributions to $\mathrm{B_q}-\overline{\mathrm{B}}_\mathrm{q}$ mixing from the Higgs potential were claimed. A systematic treatment shows that these effects are small. Also loop contributions to $\mathrm{B_q}-\overline{\mathrm{B}}_\mathrm{q}$ mixing involving Higgs bosons turned out to be small.
  The Higgs potential does not challenge the previously known correlation between $\mathcal{B}(B_s \to \mu^+\mu^-)$ and $\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing.